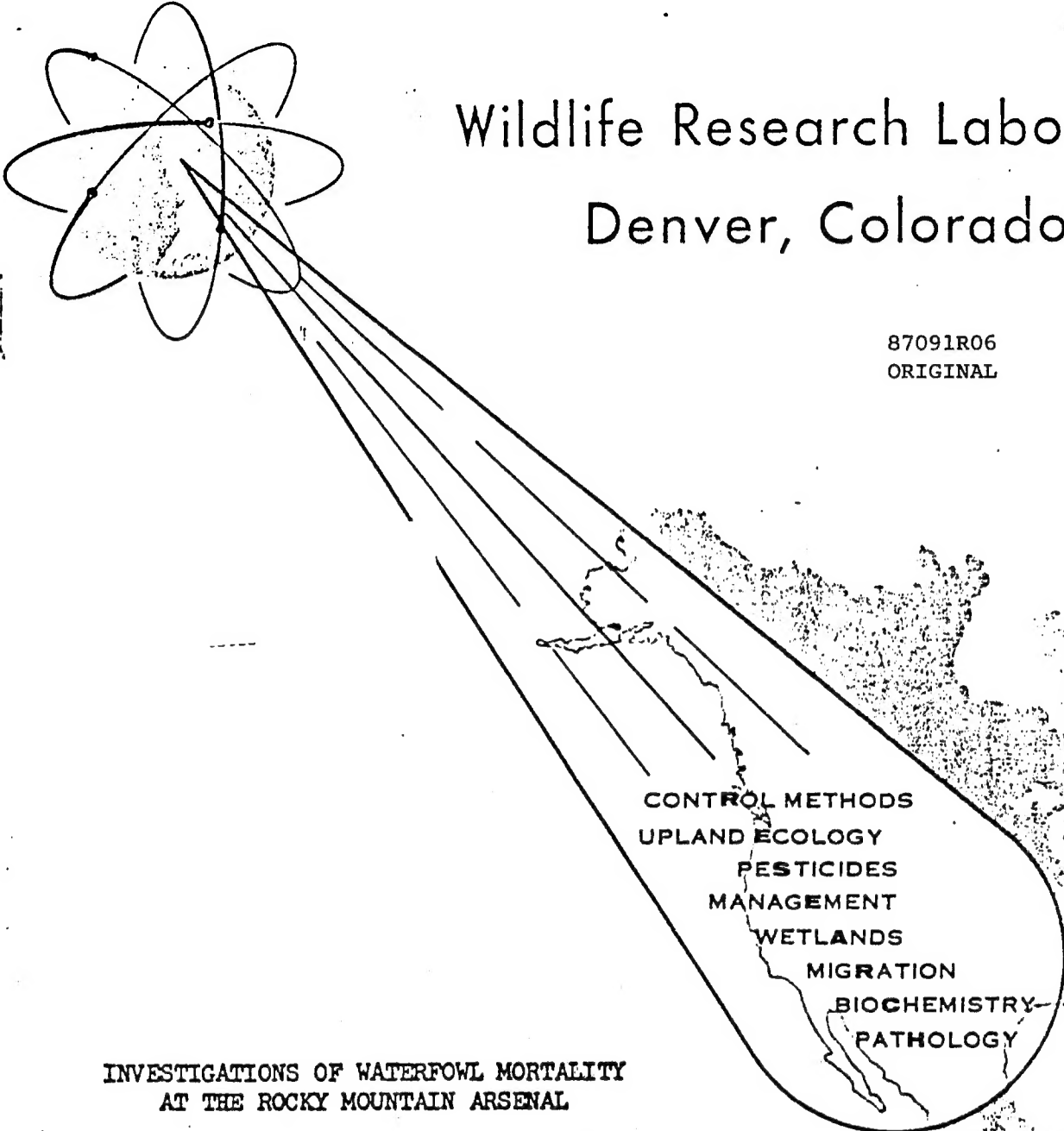


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13. ABSTRACT (Maximum 200 words) <p>IN APRIL, 1959, THE WILDLIFE RESEARCH LABORATORY STUDIED THE MORTALITY PROBLEM AT THE ARSENAL. FIELD OBSERVATIONS WERE MADE AND SAMPLES OF DEAD BIRDS, WATER, MUD, AND VEGETATION TAKEN FOR ANALYSIS. THE RESULTS OF THESE INVESTIGATIONS FORM THE BASIS OF THIS REPORT.</p> <p>IT WAS ESTIMATED DURING THE STUDY THAT 2000 DUCKS WERE LOST EACH YEAR DUE TO THE CONTAMINATION OF THE LAKES. HIGH MORTALITY OCCURRED WHEN THE WATER LEVEL DROPPED IN THE FALL AND WINTER AND AREAS OF THE LAKE BOTTOMS WERE EXPOSED. AQUATIC LIFE IS GENERALLY ABSENT FROM THE LAKES. SAMPLES FROM DEAD DUCKS, AQUATIC VEGETATION, WATER, FOAM, AND MUD CONTAINED CONCENTRATIONS OF ALDRN AND/OR DLDNR.</p> <p>EXPERIMENTS WITH TADPOLES EXPOSED TO MUD AND ALGAE FROM THE LAKES SHOWED THAT THESE TWO MEDIA WERE TOXIC ENOUGH TO KILL THE TADPOLES IN TWO WEEKS.</p>				
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INVESTIGATIONS OF WATERFOWL MORTALITY
AT THE ROCKY MOUNTAIN ARSENAL

Robert B. Finley, Jr.

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UNITED STATES DEPARTMENT OF THE INTERIOR
Fish and Wildlife Service
Bureau of Sport Fisheries and Wildlife
Branch of Wildlife Research

INVESTIGATIONS OF WATERFOWL MORTALITY AT THE ROCKY MOUNTAIN ARSENAL

by

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For many years the recurrence of waterfowl mortality at the Rocky Mountain Arsenal near Denver, Colorado, has been a cause for serious concern to the U. S. Bureau of Sport Fisheries and Wildlife and the Colorado Department of Game and Fish. This concern has also been shared by personnel of the Rocky Mountain Arsenal who have given their generous cooperation in the investigation of the problem,

The Wildlife Research Laboratory has several times since 1951 assigned research personnel to the study of this problem and issued reports of their findings. These studies have strongly indicated the cause of mortality to be the contamination of three artificial lakes with insecticide produced by a chemical plant.

In 1952, field and laboratory studies of the cause of mortality were conducted by Mr. George W. Sciple, biologist of the Wildlife Research Laboratory. He estimated that about 1,200 ducks died in the spring of 1952. Experiments indicated that the cause of death was a toxic agent or agents carried on the surface of the water and probably entering the lakes through the process-water drain from the chemical plant area. Sciple's report

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dated May 28, 1952, was submitted to the Commanding Officer, Rocky Mountain Arsenal; the Julius Hyman Co., Rocky Mountain Arsenal; the Colorado Department of Game and Fish; and the U. S. Food and Drug Administration, Denver.

In 1955, additional field observations were made by biologists of the Wildlife Research Laboratory, and bioassays and chemical analyses of duck tissues were performed by the Communicable Disease Center, Savannah, Georgia. These analyses showed that fat and liver of a dead duck from the Arsenal contained large concentrations of dieldrin. A report well summarizing the history and earlier findings was prepared by Dr. Wayne I. Jansen and submitted to the Director, Fish and Wildlife Service, on December 2, 1955.

In April 1959, the Wildlife Research Laboratory, which had recently acquired the necessary equipment and personnel to perform chemical analyses of insecticide residues, again undertook study of the mortality problem at the Arsenal. The writer and others made field observations and collected samples of dead birds, water, mud, and vegetation for laboratory analysis. The results of these 1959 investigations form the basis of this report.

Extent of Mortality

Nearly all of the waterfowl mortality has been associated with a series of three lakes south of the Shell Chemical Company plant area. These reservoirs--Upper Derby, Lower Derby, and Ladora lakes--are used for storage

and recycling of cooling water in the chemical plant. In addition to waterfowl, dead pheasants, songbirds, muskrats, rabbits, and frogs have been seen on and near the shores of these lakes.

The numbers of waterfowl that have been killed are difficult to estimate because of the transient and constantly changing nature of the migratory duck population. Large numbers of birds that have acquired doses of toxicant from the Arsenal could have flown on to sicken and die elsewhere. Therefore, counts of birds found dead around the three lakes represent the minimum losses and provide a basis for rough estimates of additional mortality.

On April 17, 1959, recently dead birds and animals were counted around the shore of Iadora Lake and along the canal that skirts the north side of the lake. A total of 119 dead birds and animals were seen, including 94 ducks of 9 species, 6 coots, 2 pheasants, 7 muskrats, 4 rabbits, and 6 frogs. If the 94 ducks all died within the preceding week, and if this mortality rate was typical for the 4-month period, January-April, the losses for this period would be approximately 1,500 ducks around Iadora Lake alone.

During this same period an employee of the Shell Chemical Company was assigned the task of periodically gathering up dead ducks and burying them. From conversation with this man it was estimated that he may have gathered 20 gunny sacks of ducks, 25 birds to a sack, or a total of 500 ducks in the first 3 months of 1959. It was obvious in April that large numbers of ducks had not been collected for disposal.

In a previous year, it is understood, a pile of about 600 dead ducks was collected at one time and photographed.

Mr. George Sciple in his report estimated losses of roughly 1,200 ducks during the period of his study (spring of 1952).

From the above lines of evidence, 2,000 ducks per year might be a conservative estimate of total duck mortality on and off the area from toxic contamination of these three lakes. Over the past 10 years that this problem has existed, cumulative losses may have been 20,000 or more ducks.

Ecology of the Lakes

Upper Derby, Lower Derby, and Ladora lakes are artificial impoundments of run-off and irrigation water that is recycled through the chemical plant for cooling purposes. Ducks wintering in the Denver area are attracted to these lakes by the ice-free condition of the relatively warm water. The basins are shallow with mud bottoms. During summer the lakes are ordinarily full and waterfowl mortality is low. In fall and winter the water level drops progressively until most of the areas of lake bottom are exposed as mud flats. High mortality of wildlife in and around the lakes seems to occur only at times when extensive mud flats are exposed. In April 1959, when counts of casualties were made, Ladora Lake was low but still of fairly large area. Most of the live ducks were then on Ladora Lake. Lower Derby was reduced to a small fraction of its former area, and Upper Derby was little more than a small pond into which a narrow channel of water from the plant effluent canal led across an expanse of mud flats. The channel of water flowing through

the bed of Upper Ladora Lake gave off a noticeable chemical odor that, after about a half hour, became increasingly unpleasant. The same odor was noticed in the chemical plant area. When the three lakes were filled in May with water from the Highline Canal, duck mortality dropped and was no longer in evidence.

It was obvious from casual inspection that the ecology of the lakes is grossly out of balance. Aquatic life in Ladora was greatly impoverished and progressively worse as inspection proceeded up the drainage to Lower Derby and Upper Derby lakes. Only a few kinds of water plants were present, and these such as cattails, sago pondweed, and filamentous algae grew in dense beds. The mud flat of Upper Derby Lake was carpeted with a mat of dried sago pondweed and filamentous algae. Rootstocks of cattails in Upper and Lower Derby appeared dead, but around Ladora Lake a belt of cattails was putting out new green leaves.

In 1948 and earlier there were fish in Ladora Lake, and convalescent patients at Fitzsimons Hospital enjoyed fishing there. I have made no effort to catch fish in any of the lakes but have been told by persons who have observed the area for many years that fish are no longer present. In April and May, when frog choruses could be heard in nearly all ponds and ditches outside the Arsenal, Laboratory biologists heard and saw none at the three lakes. Nor could we find any egg masses or tadpoles. However, a few dead frogs and one dead tiger salamander were seen. Aquatic insects and spiders were almost completely absent from the three lakes in April and May. Live aquatic snails were present in all three lakes and extremely abundant in

Upper Derby. Masses of dead snail shells, as well as abundant live snails, had accumulated in the pond around the outlet through Upper Derby dam.

Dieldrin has been previously reported to kill fish but have no harmful effect on snails in a salt marsh (Harrington and Bidlingmayer, 1958). No effort was made to collect fresh-water plankton, but swarms of tiny red crustaceans were seen swimming among masses of algae in the channel below the inlet of Upper Derby Lake.

Bioassays with Tadpoles

Having observed the absence of frog reproduction in Ladora, Lower Derby, and Upper Derby lakes, simple bioassay experiments were conducted using tadpoles of the leopard frog and the chorus frog, the two most abundant species in the Denver area. Three test aquaria and one control aquarium were set up to test effects of contaminated mud, algae, and lake water. In one test 25 tadpoles were kept in uncontaminated pond water to which mud from Upper Derby Lake had been added. They were fed algae from an uncontaminated pond. Eleven days after start of the test all tadpoles were dead.

In another test 42 tadpoles were kept in uncontaminated pond water with no mud and fed on algae from Upper Derby Lake. Twelve days after start of this test all tadpoles were dead.

In the third test 50 tadpoles were kept in water from Upper Derby Lake with no mud and fed on algae from an uncontaminated pond. Within 2 weeks 12 had died, and 49 days after start of the test all 50 tadpoles were dead.

In the control aquarium 66 tadpoles were kept in uncontaminated pond water without mud and fed on algae from an uncontaminated pond. Within 2 weeks 4 tadpoles had died, and 51 days after start of the control all tadpoles had died. Survival of tadpoles in the control was not good

because of the small makeshift nature of the aquarium, which could not be aerated, and in which the only means of removing waste products was by replacement of water.

Crude though the bioassay tests were, they showed that the survival of tadpoles in water alone from Upper Derby Lake was almost as good as survival in the control water. However, algae from Upper Derby Lake is sufficiently toxic to kill tadpoles within 2 weeks, and mud alone from Upper Derby Lake also can kill tadpoles within 2 weeks.

Chemical Analyses

Twenty samples taken from Upper Derby, Lower Derby, and Ladora Lakes between April 10 and May 4, 1959, a period of low water, were chemically analyzed for chlorinated hydrocarbon insecticides at the Wildlife Research Laboratory. Results of the analyses are presented in Table 1. The source of each sample is indicated by Arabic numerals on the accompanying map that refer to the same numerals in the table.

The samples analyzed include three ducks picked up dead at Ladora Lake, aquatic vegetation from Upper Derby Lake, water and foam from Upper and Lower Derby Lakes, and mud from all three lakes.

Nearly all samples contained measurable amounts of aldrin or dieldrin, and nearly half the samples contained other unidentified chlorinated hydrocarbons. The amounts measured varied greatly between the samples. The absence of detectable amounts of aldrin in the bird samples is not unusual because most of the aldrin entering animal tissues is converted and retained in the form of dieldrin. All three ducks analyzed contained appreciable residues of dieldrin. A composite sample from two of the ducks (3924 and

3925) was analyzed in the Laboratory using the infrared spectrophotometric method, which confirmed the presence of dieldrin.

Little information is available concerning the acute and chronic toxicities of aldrin and dieldrin to ducks and the amounts of these materials that may be accumulated in duck tissues before death, or that may be stored and tolerated without harm.

Knedel has reported mortality of juvenile and adult ducks on a lake in North Dakota that was sprayed with 2 oz. of aldrin in oil per acre (Rudd and Genelly, 1956). In Wyoming, one merganser on a small reservoir sprayed with the same amount of aldrin in oil died within 2 days. Tissue analyses of this duck revealed 31 ppm of aldrin in the brain, 24 ppm in the kidney, and 4 ppm in the liver (Post, 1952).

In experiments with pinkbills, 200 ppm of dieldrin in the diet resulted in a 50 percent loss in 1 month (Rudd and Genelly, op. cit.) Experimental sprays approximating field application rates of 0.5, 1.0, and 1.5 lbs. per acre did not seem to harm ducks. This formulation was presumably in water. An actual field application of 0.5 lbs. of dieldrin per acre resulted in the loss of at least 20 mallards and 6 coots.

The low content of aldrin and dieldrin in the water entering Upper Derby Lake from the plant effluent canal is indicative of the extremely low solubility of these compounds. Much greater amounts are carried by foam and other suspended organic matter. Aldrin and dieldrin molecules are readily adsorbed by mud particles, and the tremendous surface of all these particles acts as a great reservoir holding large quantities of insecticide for long periods after their influx has ceased.

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The range of variation in toxic content of the few mud samples taken is so great that only a rough indication of the distribution of toxic chemicals in mud is possible. The banks of the inlet canal feeding Upper Derby are very heavily loaded with dieldrin (480 ppm). Progressively less insecticide occurs in mud around the outlets of Upper Derby and Lower Derby lakes. Toxic content of mud decreases outwardly on the mud flats away from the central channel and from the surface of the mud to a depth of 1 foot.

From the known properties of chlorinated hydrocarbons and their distribution in the samples analyzed, it seems clear that the mud deposits of the three lakes have become charged with these materials brought into the lakes by the effluent canal from the chemical plant and that the mud, over a long period of time, releases small amounts of the toxicants to the water and living organisms.

Summary

An annual die-off of wildlife in the Upper Derby, Lower Derby, and Ladora lakes area of the Rocky Mountain Arsenal occurs in late winter and spring when the water level is low and mud bottoms are exposed. These lakes do not support fish, amphibians, or aquatic insects. It is estimated that losses of waterfowl alone amount to 2,000 or more birds per year.

Chemical analyses of dead birds, water, and mud samples showed the presence of aldrin and/or dieldrin. Large amounts of these chemicals have accumulated in the mud, particularly near the inlet canal and outlet of Upper Derby Lake. Although data on the toxicity of aldrin and dieldrin

to ducks is limited, the considerable amounts of dieldrin in the ducks analyzed support the conclusion that they were killed by aldrin or dieldrin or both.

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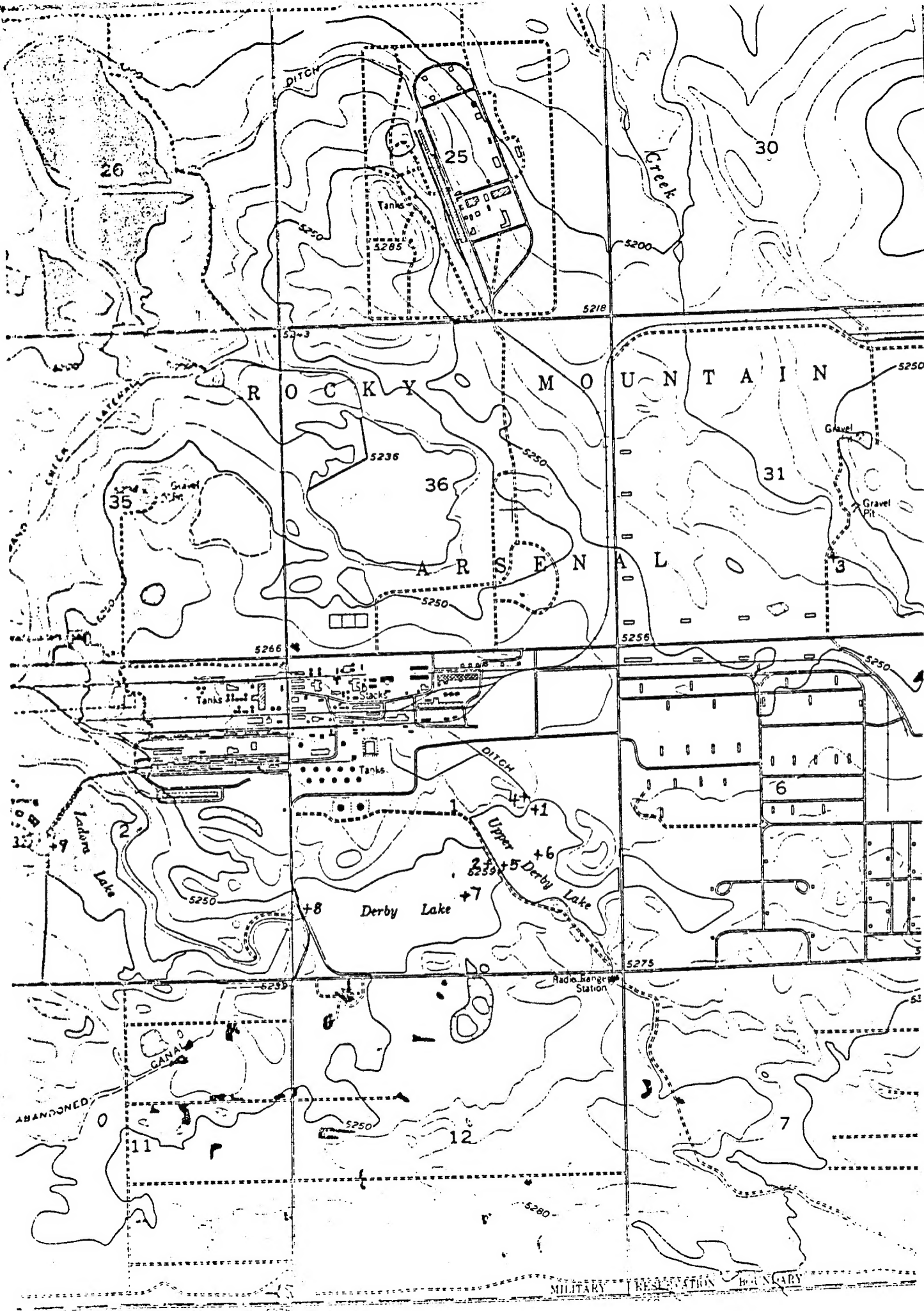


Table 1.

INSECTICIDAL CONTENT OF R.M.A. SAMPLES

Sample	Kind	Source	Aldrin	Dieldrin	Other Chlorinated Hydrocarbons
3923	Hallard	Ladora Lake	0 ppm	64 ppm	
3924	Shoveller	Ladora Lake	0 ppm	30 ppm	~15 ppm
3925	Green-winged teal	Ladora Lake	0 ppm	58 ppm	~40-50 ppm
3926	Robin	Ladora Lake	0 ppm	2.3 ppm	~0.5 ppm
3927	Wackrat	3. Pistol Range Pond	0 ppm	0 ppm	~0.15 ppm
3928	Ice algae & pondweed	6. Mud flat Upper Derby Lake	3.1 ppm	2.7 ppm	
3930	Water	1. Inlet Upper Derby Lake	.002 ppm	.002 ppm	
3931	Water & mud	2. Inlet Lower Derby Lake	1.5 ppm	0 ppm	~0.5 ppm
3933	Water & mud	2. Inlet Lower Derby Lake	0 ppm	0.5 ppm	0 ppm
3934	Water	3. Inlet Lower Derby Lake	5. ppm	9. ppm	
3935	Water	3. Pistol Range Pond	0 ppm	0 ppm	~.004 ppm
3936	Mud	4. Inlet Upper Derby Lake	Present	480 ppm	Present
3937	Mud	5. Lower end Upper Derby Lake	> 18 ppm	> 3 ppm	
3938	Mud	6. Surface of mud flat Upper Derby Lake	2.6 ppm	0.3 ppm	~0.5 ppm
3939	Mud	6. Six inches below surface Upper Derby Lake	0.3 ppm	0 ppm	~1. ppm
3940	Mud	6. One foot below surface Upper Derby Lake	0 ppm	0 ppm	~0.5 ppm
3941	Mud	7. Upper end Lower Derby Lake	0.6 ppm	0 ppm	0 ppm
3942	Mud	8. Outlet Lower Derby Lake	1. ppm	0.4 ppm	
3943	Mud	8. Outlet Lower Derby Lake	0.01 ppm	0.04 ppm	
3944	Mud	9. Lower end Ladora Lake	> 0.05 ppm	0 ppm	0 ppm